BIPOLAR PLATE WITH TWO-PASS ANODE

CROSS-REFERENCE TO RELATED APPLICATIONS

This invention claims priority to U.S. Provisional Patent Application Serial Number 60/427,095.

FIELD OF INVENTION

This invention relates to fuel cells, bipolar plates for fuel cells, indirect internal reforming of fuel for fuel cells, and to methods of providing two passes of anode reactant through a bipolar plate for fuel cells.

BACKGROUND OF THE INVENTION

A fuel cell stack consists of multiple planar cells stacked upon one another, to provide an electrical series relationship. Each cell is comprised of an anode electrode, a cathode electrode, and an electrolyte member. A device known in the art as a bipolar separator plate, bipolar plate, an interconnect, a separator, or a flow field plate, separates the adjacent cells of a stack of cells in a fuel cell stack. The bipolar separator plate may serve several additional purposes, such as mechanical support to withstand the compressive forces applied to hold the fuel cell stack together, providing fluid communication of reactants and coolants to respective flow chambers, and to provide a path for current flow generated by the fuel cell. The plate also may provide a means to remove excess heat generated by the exothermic fuel cell reactions occurring in the fuel cells.

Some bipolar separator plates include an integral coolant chamber or coolant flow passage, which may be designed for gaseous coolant, liquid coolant, or endothermic fuel reforming. A coolant flow passage may be centrally located between two outer metallic sheets, each of which is die-formed with a plurality of grooves, or ribs. The cooling chamber is formed when the maximum elevation of one sheet rests on the maximum depression of the subsequent sheet. Both sheets are structural members of the bipolar plate and therefore must

be of sufficient strength and robustness to withstand the compressive sealing force applied to the assembled fuel cell stack. U.S. Patent No. 5,795,665 to Allen teaches a "reforming compartment" within an MCFC bipolar separator plate formed when the maximum elevation of a dimpled single-piece bipolar separator rests on the maximum depression of a dimpled subassembly of active components and current collector with a flat sheet barrier disposed between the two components. The resulting chamber is equipped with a reforming catalyst for endothermic stream reforming of fuel.

Various alternatives for flow configuration in the bipolar separator can be found in the various reactant flow and reactant manifold designs. The existing alternatives for flow configuration are co-flow, counter-flow, and cross-flow, as well as variations utilizing serpentine flows. The existing designs for reactant and coolant manifolds are internal, external, or a combination of internal and external. Manifolding the fuel, oxidant and coolant to provide uniform flow to the surfaces of the bipolar separator plate contributes to the overall design complexity.

It is an object of the present invention to provide a bipolar plate that reduces or overcomes some or all of the difficulties inherent in prior known devices. Particular objects and advantages of the invention will be apparent to those skilled in the art, that is, those who are knowledgeable or experienced in this field of technology, in view of the following disclosure of the invention and detailed description of certain preferred embodiments.

SUMMARY

Preferred embodiments of the present invention can provide a primary flow path for an indirect internal fuel reformer and a secondary flow path for an anode flow field within a bipolar plate equipped with a center flow chamber. The center flow chamber is fluidly coupled with an anode flow field in a manner that provides for the anode reactant fuel to pass through the fuel cell bipolar plate twice.

The entire flow path through the bipolar plate comprises a first internal manifold within a first edge area of the bipolar plate that is fluidly coupled to the center chamber of the bipolar plate. The center chamber of the bipolar plate comprises a plurality of flow channels

that are fluidly coupled to a turnaround plenum located in an opposing second edge area of the bipolar plate. The turnaround plenum is fluidly coupled through a plurality of apertures to an anode flow field of the bipolar plate. The anode flow field is comprised of a plurality of flow channels nested with the flow channels of the center chamber and is fluidly coupled with a second internal manifold in the first edge area of the bipolar plate.

In accordance with a first aspect, a fuel cell bipolar plate includes a first plate having a first surface, an opposing second surface, and a plurality of ribs defining anode flow channels on the first surface of the first plate. A second plate has a first surface, an opposing second surface, and a plurality of ribs defining cathode flow channels on the second surface of the first plate. The second plate is nested with the first plate so as to define a plurality of center flow channels extending between the first and second plates. A first edge area is formed at one end of the first and second plates and a second edge area is formed at an opposed end of the first and second plates. A plurality of first internal fuel manifolds is formed in the first edge area and is in fluid communication with the center flow channels. A plurality of second internal fuel manifolds is formed in the first edge area and is in fluid communication with the anode flow channels. A turnaround plenum is formed in the second edge area, and the turnaround plenum is in fluid communication with the center flow channels and the anode flow channels.

In accordance with a second aspect, a fuel cell bipolar plate includes a plate formed of a first plate and a second plate and comprising plurality of segments. The first plate has a first surface, an opposing second surface, and a plurality of ribs defining anode flow channels on the first surface of the first plate. The second plate has a first surface, an opposing second surface, and a plurality of ribs defining cathode flow channels on the second surface of the first plate. The second plate is nested with the first plate so as to define a plurality of center flow channels extending between the first and second plates. A first edge area is formed at one end of the first and second plates and a second edge area is formed at an opposed end of the first and second plates. A first internal fuel manifold is formed in the first edge area of each segment and is in fluid communication with the center flow channels. A second internal fuel manifold is formed in the first edge area of each segment and is in fluid communication

with the anode flow channels. A turnaround plenum is formed in the second edge area, and the turnaround plenum is in fluid communication with the center flow channels and the anode flow channels.

These and additional features and advantages of the invention disclosed here will be further understood from the following detailed disclosure of certain preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

The aspects of the invention will become apparent upon reading the following detailed description in conjunction with the accompanying drawings, in which:

FIG. 1 is a plan view of a bipolar plate of the present invention.

FIG. 2 is a cross section of the bipolar plate of FIG. 1 taken along line 2-2 of Fig. 1.

FIG. 3 is a cross section of the bipolar plate of FIG. 1 taken along line 3-3 of Fig. 1.

FIG. 4 is a perspective view, shown partially cut-away, of the bipolar plate of FIG. 1, illustrating a turnaround plenum and an aperture.

FIG. 5 is a schematic representation of reactant flow paths through the bipolar plate of FIG. 1.

The figures referred to above are not drawn necessarily to scale and should be understood to present a representation of the invention, illustrative of the principles involved. Some features of the bipolar plate with a two-pass anode depicted in the drawings have been enlarged or distorted relative to others to facilitate explanation and understanding. The same reference numbers are used in the drawings for similar or identical components and features shown in various alternative embodiments. Bipolar plates with a two-pass anode as disclosed herein would have configurations and components determined, in part, by the intended application and environment in which they are used.

DETAILED DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

In FIG. 1, a bipolar plate 1 with a center chamber formed of flow channels is shown in plan view comprising a series of repeated segments 2 that are an artifact of the progressively tooled stamping dies that form the bipolar plate 1. Bipolar plate 1 is further

comprised of first internal fuel manifolds 3 and second internal fuel manifolds 4 within first opposing edge area 5 of the bipolar plate 1. The bipolar plate is further comprised of a second opposing edge area 6. A ribbed active area 7 of the bipolar plate is seen positioned between first and second opposing edge areas 5, 6. A turn-around plenum 21, seen in FIG. 3 and described in greater detail below, is positioned within second opposing edge area 6. Internal manifolds 3, 4 of the first edge area 5 are adjacent to one another and, in a preferred embodiment, are arranged so that the centers of internal manifolds 3, 4 for a particular segment 2 of bipolar plate 1 are on a line that extends substantially parallel to the general flow path of the bipolar plate 1 through active area 7.

A description of a bipolar plate and a method of forming such a plate is found in U.S. Patent Application Serial No. 09/714,526, entitled "Fuel Cell Bipolar Separator Plate and Current Collector Assembly and Method of Manufacture," filed on November 16, 2000, the entire disclosure of which is incorporated herein by reference.

FIG. 2 is a cross section of the bipolar plate 1 taken along line 2-2 of FIG. 1. The bipolar plate 1 is comprised of a first sheet 10 and a second sheet 11, each preferably formed of metal. The first sheet 10 and second sheet 11 comprising the bipolar plate 1 are produced with patterns of flow structure produced by the same progressive stretch-forming tool. The structure of the first sheet 10 is stamped such that it has ribs with a greater depth 12 than ribs formed in the second sheet 11. As a result, the two sheets of material will nest when joined together, creating center flow channels 13 within ribbed active area 7, between the first and second sheets 10, 11. A first surface 14 of the second sheet 11 that faces first sheet 10 is lined with a catalyst 15 within center flow channels 13 of bipolar plate 1. The catalyst 15 is comprised of any of those catalysts known in the art to promote steam reforming of methane. Anode flow channels 16 are formed on outwardly facing first surface 17 of the second sheet 11 and extend along ribbed active area 7. An inwardly facing surface of second sheet 11 forms a part of center flow channels 13. Cathode flow channels 18 are formed on an outwardly facing second surface 19 of the first sheet 10 and extend along ribbed active area 7.

In FIG. 3, bipolar plate 1 with center flow channels 13 is shown in section, in a view taken along line 3-3 of FIG. 1. As noted above, a turnaround plenum 21 is formed within

second edge area 6, and is in fluid communication with center flow channels 13. Apertures 22 are formed in second edge area 6, providing fluid communication between turnaround plenum 21 and anode flow channels 16. Thus, a fluid flow path exists from first internal fuel manifolds 3 located within first edge area 5, through center flow channels 13, through turnaround plenum 21 and apertures 22 within second edge area 6, through anode flow channels 16, and out to second internal manifolds 4 within first edge area 5. As noted above, catalyst 15 is deposited on surface 14 of first sheet 10 within flow channels 13.

In FIG. 4, an isometric cut-away of the bipolar plate 1 is shown. Each of a plurality of apertures 22a, 22b, and 22c is seen to be at the terminal ends of a corresponding anode flow channel 16a, 16b, 16c of the second sheet 11 and within the second edge area 6. A spacer 28 is found in second edge area 6, and serves to ensure that the portion of bipolar plate 1 folded back on itself to form second edge area 6 has the proper alignment with the top surface of the remainder of bipolar plate 1. A plurality of flat wires 24 are positioned on first sheet 11. An electrode 26 is positioned on flat wires 24 such that reactant gasses flowing through anode flow channels 16a, 16b, and 16c can react with electrode 26. Further description of the use of such flat wires is provided in commonly owned U.S. Patent No. 6,383,677, entitled "Fuel Cell Current Collector," issued on May 7, 2002, the entire disclosure of which is incorporated herein by reference for all purposes.

On the first pass of the reactant through center flow channels 13 of bipolar plate 1, the composition of the anode reactant is a mixture of methane, steam, and recirculated anode exhaust. Catalyst 15 on surface 14 of center flow channels 13 promotes steam reforming of the methane. The composition of the anode reactant provides the ability to achieve equilibrium methane conversion of 99.9 percent in the presence of the steam reforming catalyst. The reformed anode reactant flows out of center flow channels 13 to turnaround plenum 21.

On the second pass, after passing through turnaround plenum 21 and aperture 22, the reformed anode reactant will reverse its direction of flow through bipolar plate 1 and pass through anode flow channels 16. The anode reactant will enter the anode flow field and electrochemically react on anode electrode 26 of the fuel cell. Thus, center flow channels 13

are fluidly coupled with anode flow channels 16 in a manner that provides for the anode reactant fuel to pass through the fuel cell bipolar plate twice.

In FIG. 5, a preferred embodiment of an anode reactant flow path 40 and a cathode reactant flow path 41 are schematically shown relative to each other. In this embodiment, cathode flow path 41 flows counter to the direction of flow of anode flow path 40 as the anode reactant passes through anode flow channels 16. Cathode flow path 41 is coincident with anode reactant flow path 40 as the anode reactant passes through center flow channels 13. It is to be appreciated that other flow path configurations, such as counter-flow and cross-flow, are considered to be within the scope of the present invention.

In light of the foregoing disclosure of the invention and description of the preferred embodiments, those skilled in this area of technology will readily understand that various modifications and adaptations can be made without departing from the scope and spirit of the invention. All such modifications and adaptations are intended to be covered by the following claims.